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biocontrol systems

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The human organism contains many very complicated and sophisticated feedback systems. Examples of such systems are those that arise in the regulation of body temperature, sugar level in the blood, carbon dioxide in the tissues, etc. Such systems are called biological-control systems or biocontrol systems. The study of biocontrol systems is still in its early stages, and the research area is not yet thoroughly investigated. To date most of the research has been done by physiologists and little by control engineers. In order to indicate to the physiologist the vast control theory available for the study of biocontrol systems and to stimulate the control engineer's interest in biocontrol systems, a survey [1] of the work on biocontrol systems has been written. This survey reviews the various aspects of biological-control systems and their relation to feedback theory. The material discussed in the survey is classified into the following topics: (1) General Human Dynamics; (2) Neuromuscular Systems; (3) Eye Dynamics; (4) Biological Regulatory Systems; (5) Biological Process Control; (6) Central Nervous Systems and Brain.

The survey was sponsored by the Applied Mathematics Division of AFOSR as part of a program of research on sampled-data systems with Professor Eliahu Jury of the University of California (Berkeley). [Sampled-data systems are characterized by signals which are known only at discrete intervals of time.]

Recent studies have indicated that a discrete representation of certain biocontrol systems is better suited than a continuous representation. This result represents a major step in the understanding of biocontrol systems by the precise simulation of their actual behavior. To

exploit this result, the Applied Mathematics Division is now supporting research in the mathematical study of Biocontrol Systems by Professor Jury. Applications of sampled-data theory will first be attempted in the study of the eye and the neuromuscular system dynamics, and then introduced later to other parts of the human system. Results will be reported in future issues of the OAR Research Review.

[1] Jury, E. I. and Pavlides, T., "A Literature Survey of Biocontrol Systems." To be published in the IEEE Transactions of Automatic Control.

4000 mile *Balloon Flight*

CHARLES S. TILTON, Aerospace Instrumentation Laboratory, AFCRL

A four-thousand-mile flight by an AFCRL superpressure balloon was terminated on 16 June after a 28-day journey across the Pacific. It had reached a point 500 miles south of the Kamchatka (Siberia) peninsula. The balloon was destroyed by radio command from Chico, California, from where it was launched on 19 May. It had remained at a constant 80,000-ft. altitude without the use of ballast throughout the 28-day period.

This was the third successful flight in a series conducted by AFCRL to evaluate the superpressure design feature. In the summer of 1962, a smaller balloon of this design set a record by remaining aloft for 30 days. The first in the series, launched in May 1962, stayed aloft for 19 days and travelled a distance of 6,000 miles. In all three cases, the flight duration was limited by the balloon's approaching the Asian mainland rather than by technical considerations.

Positive control of and radio contact with the balloon were maintained by AFCRL personnel at Chico throughout its flight. Internal balloon pressure and temperature, ambient temperature, and the instrument package's internal temperature were some of the readings transmitted constantly to Chico from the balloon. The flight was also monitored by the FCC.

More than 300 environmental chamber tests of balloon models preceded the series of superpressure balloon flights now being made by AFCRL. The 54-ft. balloon was made of a laminated material consisting of two layers of .75 mil mylar. Future plans call for an 84-foot balloon to fly at an altitude of 100,000 feet with a 100-pound pay load.

AUTOMATIC ANALYSIS of FERROMAGNETIC MATERIALS

TOM G. PURNHAGEN, Captain, USAF, Microwave Physics Laboratory, AFCRL

From ferromagnetic materials (such as yttrium-iron-garnets) may come a variety of new microwave devices--oscillators, amplifiers, phonon generators, delay-lines, and so on. These materials are, therefore, under rather intensive study. "Study" entails many things--growing crystals, designing experimental devices, and recording data. It also involves the analysis of the properties of the ferromagnetic material itself.

One of the properties that govern performance of a particular ferromagnetic material is its spin-wave characteristics. Spin wave is a term used to describe the magnetic precession of atoms in a crystal structure. When the magnetic moments of the adjacent atoms are slightly out of phase, spin waves result. Precession is analogous to the wobble of a spinning top. By controlling these precessions, we have a mechanism for storing energy and converting it from one form to another. This mechanism does not come into play until the instability threshold is reached. Therefore, it is important that we know the instability threshold for a given ferromagnetic material. This threshold varies as a function of the applied DC magnetic field. One of the methods for characterizing the properties of a given ferromagnetic material is by plotting spin-wave instability threshold as a function of an applied magnetic field. Done manually, the plotting of spin-wave instability thresholds is a tedious and time-consuming process.

A system which automatically plots spin-wave instability threshold versus DC magnetic field for ferromagnetic materials has been developed by AFCRL under the direction of Capt Tom G. Purnhagen. Such plots, sometimes called butterfly curves, can be used in the determination of spin-wave linewidth, in the investigation of spin-wave phonon interactions, and in the study of anisotropy effects.

Even if the data are plotted manually with extreme care, a process requiring about eight man-hours per plot, there are some serious deficiencies in this method. First, the frequency and temperature stability requirements are very stringent, and often prohibitive. Second, point-by-point data collection may miss important fine detail

in the curve. Third, irregularities in the curve may be misinterpreted as point scatter, or vice versa.

The automatic-plotting system relaxes the stability requirements by reducing the actual data collection time from about two hours to about ten minutes per plot. The curves plotted are continuous, eliminating the possibility of skipping over or misinterpreting irregularities. The number of man-hours required per plot is reduced by at least a factor of ten.

The heart of the automatic-plotting scheme is a servosystem which locks the microwave power level at the spin-wave threshold while the applied magnetic field is varied. An X-Y recorder continuously plots microwave power versus applied field; thus the butterfly curve is obtained directly and continuously.

fame is where you find it

DR. AMOS G. HORNEY
Directorate of Chemical Sciences, AFOSR

Some people have an overpowering drive to spread their reputation-- to have their name known as widely and as permanently as possible. Others, perhaps in anticipation of more tangible rewards, are anxious to aid in spreading the fame of their superiors. Consider, for example, the case of Capt James Cook and the Hawaiian Islands. When Cook discovered these lush tropical isles in 1778, he named them the "Sandwich Islands" after John Montague (1718-1792), Fourth Earl of Sandwich (who just happened to be First Lord of the Admiralty that year). Whether the captain would have "made admiral" by thus immortalizing his chief is not known, since he did not survive a regrettable meeting with the natives shortly thereafter.

Due to the unpredictable vagaries of language, the undying fame of the earl is not due to Hawaii, but to his obscure connection with the customary lunch of most Americans-- the "sandwich." In many regions of the world, for instance Scandinavia, the use of <u>two</u> slices of bread to enclose food is considered faintly barbaric; thus the earl's name is not, as yet, a household word. However, due to the international nature of science, the term, "sandwich," is now being introduced in a rather peculiar manner.

In 1951 Professor Peter L. Pauson, now at the University of Glasgow, discovered an entirely novel class of chemical compounds, in which a metal atom is "sandwiched" between two flat organic groups. The prototype of this class of compound is ferrocene, $Fe(C_5H_5)_2$ (fig I). These so-called "sandwich" compounds have created world-wide interest, even in countries where the food item is not popular. Their unusual physical and chemical properties suggest various commercial and military uses, in polymers, fuels, screening smokes, etc.

In recent years Prof. Pauson, under AFOSR sponsorship, has devised a large variety of reactions which modify the organic groups on ferrocene-like compounds. These "well-garnished" sandwich compounds continue to sustain interest in this area of chemistry and, incidentally, continue to spread the name, "sandwich," much more effectively than Capt Cook's earlier attempt.

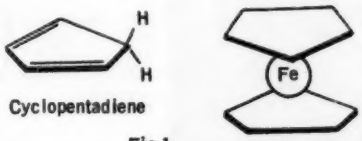


Fig 1

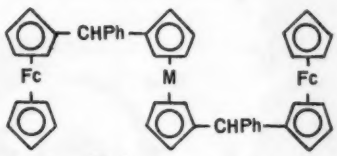


Fig 2

Prof. Pauson has directed particular attention to the synthesis of derivatives which cannot be made by straightforward methods, and which themselves may be used as starting materials for further synthetic steps. Examples are diferrocenylmethane, compounds containing several ferrocenes linked by one or two carbon side chains ("torpedo sandwich") (fig II), ferrocene derivatives bearing easily replaced dialkylaminomethyl groups and those with phosphonus directly linked to the iron atoms.

The Royal Society encouraged Capt Cook; this encouragement was not too expensive. The Air Force encourages Major Cooper in the exploration of space, but this is more expensive. The Air Force also supports the work of Prof. Pauson, who in his own field has a record of discovery perhaps equal to either of the former. Even if the name, "Sandwich Islands," has fallen into disuse, Cook's exploratory tours in 1778 have had an impact in 1963 beyond the imagination of his time Beyond, or perhaps in spite of, the facetious nomenclature "sandwich compounds," Pauson's discoveries will have undreamed-of importance in 2136.

HURRICANE SPIRAL BANDS

DR. DAVID ATLAS
Meteorology Laboratory
AFCRL

Looking down on a hurricane from above, we see a number of spiral bands extending outward from the central turbulent storm area. But we don't have to observe the hurricane from above to see this pattern. Radar serves just as well. Since 1944, when radar first showed the spiral-band structure of hurricanes, there has been a generally accepted explanation for the mechanism that creates these bands. It now appears that this long-held explanation may be wrong. The dynamics--at least for certain of these bands--is altogether different from our former model.

It has been believed that these bands were generated by relatively narrow regions of convergence which gave rise to intense convection. The bands thus traced an arc along which the warm air near the surface was transported upward. (Convective mechanisms such as this create a variety of familiar cloud structures from summer cumulus to giant thunderstorms.) By careful radar observations of these spiral rain bands, a group of AFCRL scientists headed by Dr. David Atlas has concluded that spiral bands are predominantly of a stratiform type with only a small region of active convection at their upwind ends. According to this new model, the spiral bands are simply plumes of stratiform precipitation and are formed by horizontal air movements with only minor upward velocities.

The small regions of active convection, however, play a strong role in the model. We can picture the hurricane as containing a number of convection columns which give rise to convection clouds at a few preferred locations of the cyclone system. These convection clouds spew out precipitation particles in the form of ice or snow which stream inward along a spiral path. But what initiates the small upward velocities which are necessary for the occurrence of stratiform precipitation? This is caused initially by the evaporation and melting of ice crystals in the plume. The evaporation of the ice crystals results in a cooling effect--and this creates an area of decreased stability into which more precipitation particles from the convection clouds are drawn. Therefore, one of the most novel features of this hypothesis is that the spiral plume itself initiates the convergence (by the cooling process). The convergence does not initiate the spiral plume.

An independent observation which is in agreement with the notion of a cooling mechanism at work is that temperatures within the spiral bands are generally cooler than those outside. Another observation supporting the hypothesis is the fact that only about three or four per cent of the hurricane area is covered by "hot" convective (thunderstorm-like) towers. Most of the rain area is contained within the bands of stratiform precipitation.

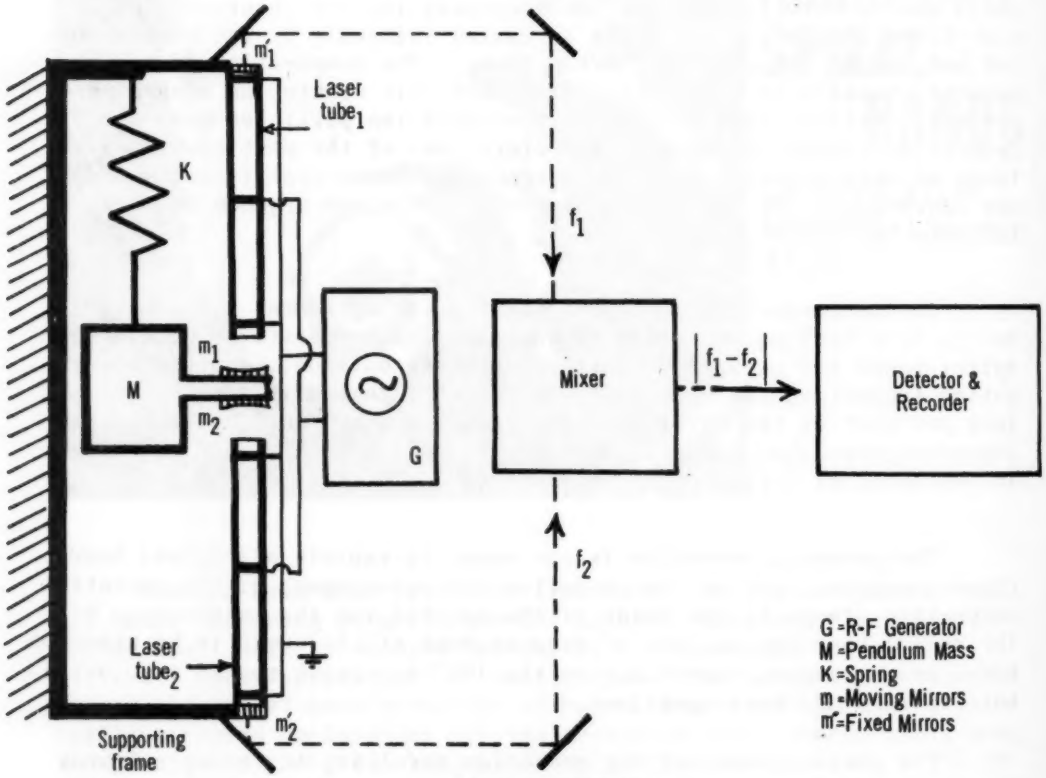
The proposed mechanism is not meant to explain all spiral bands. Other questions such as the character and arrangement of the essential convective clouds at the heads of the spirals and the maintenance of the spiral band for periods of over an hour still remain to be answered. Radar measurements planned during the 1963 hurricane season may contribute answers to these questions.

The revised model of the mechanism resulting in the spiral bands was discussed for the first time in a paper presented by Atlas at the Third Technical Conference on Hurricanes last June, in Mexico City.

USE OF OPTICAL MASERS AS TRANSDUCERS FOR SEISMOGRAPHS

HOWARD W. LEAF, Major, USAF
Geophysics Division, AFOSR

Work is presently under way at the Lamont Geological Observatory of Columbia University to design and construct a series of seismographs, both of pendulum and strain types, which will use optical maser transducers. The general advantages of the gaseous optical maser for this application are its high sensitivity and its great dynamic range. A



LASER SEISMOGRAPH

Figure 1

decided advantage adhering to the use of optical maser transducers for a seismograph is that the great sensitivity available will make possible the use of a short-period seismograph to cover the entire normal spectrum of seismic disturbances. It is a well-known fact of seismology that good long-period seismographs are difficult to construct because of thermal and other noise problems.

The general arrangement of a vertical-component optical maser seismograph is shown schematically in Figure 1. A spring (K) supports the pendulum mass (M) which has mirrors attached to its top and bottom surfaces. There are two He-Ne gaseous optical masers, operating in the infrared, located above and below the pendulum mass. Each optical maser has one mirror attached to the maser tube, and is arranged so that the pendulum-mounted mirrors form the opposite ends of the two optical resonant cavities. Movement of the pendulum mass thus shortens one optical cavity while lengthening the other, causing oppositely directed frequency changes in the masers. Light from the two masers is then mixed in a photomultiplier tube to produce a "beat" signal in the VHF range, whose frequency is the difference between the two optical maser frequencies. It is this beat, which varies with displacement, which is analyzed to provide a record of earth movements. The mixture of helium and neon gas in the maser is excited by an r.f. generator shown in the diagram as G. The reason for using two maser tubes is twofold: first, thermal-expanson effects can be largely cancelled out by this arrangement; second, this procedure obviates the necessity for maintaining an absolute frequency standard, since only the difference frequency of the mechanically coupled oscillators need be detected to provide the desired information. The horizontal-component seismograph is similar in principle.

The seismographs now under construction are expected to have a useful dynamic range of 10^7, or 140 db, and are expected to cover the entire period range of seismic events from $\frac{1}{10}$ second to 40,000 seconds or longer. These seismographs should be a minimum of one order of magnitude more sensitive than existing types, and should make it possible to reach the noise background for the first time in the 20-to-60-second period range. This improved sensitivity may aid in the detection of nuclear explosions, and will provide information on the free vibrations of the earth and solid tides of the earth with a sensitivity approximately two orders of magnitude better than is now possible.

The above research, conducted by Drs. L. E. Alsop and G. H. Sutton, is sponsored by the Geophysics Division of the Air Force Office of Scientific Research as part of the Advanced Research Projects Agency's Vela-Uniform Program.

PROBING THE FUNCTIONAL PATHWAYS OF THE BRAIN

B. D. STOLLAR, Captain, USAF, Biological Sciences Division, AFOSR

Neurophysiologists have long been exploring the brain with the aim of compiling a complete road map of pathways leading to and from it, and between its various parts. What are some of the methods used to gather the data for this map?

Classical studies have been carried out by painlessly applying a small electrical stimulus to parts of the brain in experimental animals or in patients undergoing neurosurgery. The application of such stimuli to some areas has produced definite patterns of response. In this way, brain surface areas involved in the control of localized movements, more general movements, and specially coordinated functions such as speech have been found. Special areas involved in the interpretation of incoming signals which provide sensations of hearing, vision, smell, and touch have been defined. Another area, when stimulated, has provided sudden recall from distant memory. But not all parts of the brain give rise, upon stimulation, to such specifically observable effects.

A second approach is to observe the loss of function which results from the natural or experimental loss of some brain structure. Much of our knowledge concerning the control of coordinated movement by the cerebellum, for example, has come from observing patients in whom this structure has been destroyed by illness. The loss of some structures leads to an interference in the conduction of nerve impulses which produce sensory experience. By observing the effects of localized tissue destruction, at various levels, it has been possible to trace the pathways of the nerve bundles which bring the sensory information to the brain surface or cortex. Similarly, one can outline the pathways of motor nerve bundles carrying instructions from the movement-directing areas of the cortex to the muscles in the periphery.

These two techniques have provided a great deal of information concerning the localization of brain functions. However, we are left with the most subtle functions uncovered since these methods do not disclose many of the coordinating and interconnecting pathways between the different areas. Many such interconnections, found by other means, appear to provide fine control by inhibiting or facilitating the functions of areas and pathways described above.

A third type of approach, which has been applied extensively by an AFOSR grantee, Dr. D. Hubel of the Harvard Medical School, involves the placing of recording electrodes in various positions in the brain. When electrical activity passes through the portion containing an electrode, a signal will be generated and recorded. For example, we might place the recording electrode on the surface of the brain where direct stimulation produces visual sensation. If a light is then flashed before the eye of the subject, giving rise to a sensory message from the receptors in the eye, electrical activity will be detected at the surface as soon as the sensory message arrives. In these experiments, the recording electrode is measuring an "evoked" response elicited by the distant stimulus. In a more refined way, a minute microelectrode may be placed within a single nerve cell in this "visual cortex." Electrical activity will then be recorded only when the light in front of the eye comes from a specific portion of the total visual field. Dr. Hubel has used this microelectrode technique in experiments with anesthetized cats, and has recorded from several levels between the eye and the interpretive visual cortex. He has recorded from single nerve cells and from single nerve fibers, and has determined some of the ways in which the primary visual information is rearranged and processed along the visual pathway.

It is also possible to apply the technique of recording evoked responses to the problem, mentioned above, of determining interconnections between different parts of the brain. If a recording electrode is placed in one area and a small electrical stimulus applied in another, one can determine whether there is specific conduction of the applied stimulation from its origin to the location of the recording electrode. If there is, it may be possible to trace the course of conduction by serial stimulations between the two points.

Furthermore, the technique of electrode-recording of evoked responses may be combined with the technique of producing localized destruction of small areas of the brain in animals under anesthesia. One then looks to see if the conduction pathway between the site of stimulation and the site of recording has been interrupted by specific tissue loss. One of the methods for producing such tissue loss is by

surgical removal; but there has been a search for more refined techniques to produce smaller and more localized lesions.

An AFOSR grantee, Dr. B. Larsson of Uppsala, Sweden, has devised one such method. By carefully focusing a high-energy proton beam (185 Mev, emitted by a 230-cm synchrocyclotron), he has irradiated regions as small as a few cubic millimeters. This method obviates the requirement for surgery. Dr. Larsson is currently studying the effects of such local irradiation on the function of a part of the brain which controls many automatic body functions.

A different approach has been taken by Dr. D. Albe-Fessard, working under an AFOSR grant at the College de France. She has devised a small probe, the tip of which can be refrigerated. When inserted into a localized area of the brain and cooled, this tip also cools a small portion of the surrounding brain tissue. The cooling blocks nerve impulse conduction by this tissue. A major advantage of this technique is that the functional block is reversible; as soon as the probe is moved to a new region or is removed, impulse conduction begins again in the rewarmed region.

The cooling probe is 1.2 mm in outside diameter. It is tubular and closed at the lower end; within it there is another tube of smaller diameter. The tip of this inner tube opens within and near the end of the outer tube. Compressed propane or butane is introduced into the inner tube and is forced out of its open tip. The gas then expands in the space surrounding the inner tube, cooling the tip of the probe; it then rises and is forced out of the entire unit on the outside. A localized portion of brain tissue can be cooled very quickly to nearly freezing temperature within several seconds. The extent of the cooling can be confined to a few cubic millimeters. Moderate cooling causes no permanent defect.

In initial experiments with this probe, Dr. Albe-Fessard has studied conduction of sensory information through a specific region of the thalmus, a deep brain structure which has some of the functions of a switchboard in relaying incoming sensory information.

The brain road map becomes more complex as combinations of these techniques reveal more interconnections between different functional areas. The knowledge gained contributes to our understanding of the way in which the brain controls our performance and behavior, though we are still far from approaching a full attainment of the goal.

COMPUTER RECOGNITION OF SPOKEN WORDS

PHILIP LIEBERMAN
Data Sciences Laboratory, AFCRL

If a word is carefully and separately enunciated, a computer can be taught to recognize it. But quite sophisticated preprocessing equipment is needed, and it helps if the same speaker is used all the time since different speakers, obviously, have different voice qualities. AFCRL, over a two-year period, has investigated the prospect of direct voice communication with the computer. The results are encouraging insofar as individual words are concerned. But what of words strung together in sentences?

Here we enter a new realm of difficulty. Words taken from the context of conversational speech often present an entirely different spectrum of amplitudes and frequencies than the spectrum of individual words.

In present schemes, the computer must deal with the physical acoustics of speech-not with grammar, semantics, or familiar word groupings. It cannot make inferences or reconstruct slurred words based on their context in the sentence. How would a human subject fare were we to impose on him the same constraints on word perception that are faced by the computer? This question led AFCRL to undertake a perception study to see how well people are able to comprehend spoken words extracted from the context of sentences. This study was designed to reveal those attributes of speech most important to the understanding of spoken words.

The study dealt largely with the intelligibility of short samples of speech excised from longer utterances. It was found, starting with very short samples and then adding to them, that apparently the length of an utterance must have a certain minimum duration, actually about 800 msec, before it is completely understood by a listener. This is true whether the speech is slow, normal or fast. Slow speech allows more precise articulation, but there is less context; on the other hand, for fast speech, articulation may be less precise but more context occurs in a given time. The balance between these two elements appears to hold not only for speech read from text, but for casual con-

versational speech as well. In other words, people rely on context for intelligibility when the signal is degraded by unprecise articulation.

It was shown that, when a word is spoken as part of a meaningful sentence, the context of the entire sentence affects how the word is pronounced and subsequently how intelligible it is in isolation. The tests also disclosed that the smaller the likelihood of the word's occurring in a particular sentence, the more carefully the speaker pronounces the word. The speaker may modify his production of a word on the basis of the context which follows it in the sentence, and this leads to the conclusion that the speaker usually formulates the structure of the sentence, or its principal elements, before he embarks on it.

The role of context in human-speech production and perception carries important implications for automatic speech-recognition devices. Computer speech recognition will never get beyond the stage of imperfect laboratory demonstrations if the computer ignores grammatical and semantic content.

IN CONTROL THEORY

BERNARD S. MORGAN, JR., Major, USAF
Applied Mathematics Division, AFOSR

At the recent 1963 Joint Automatic Control Conference held at the University of Minnesota, prizes were awarded to two AFOSR-sponsored papers. The research leading to these papers was supported by the Applied Mathematics Division, AFOSR.

Professor Shinzo Kodama of the University of California (Berkeley) was awarded the Prize of the IEEE Professional and Technical Group on Automatic Control for the best paper in the field for 1961-1962. The award was made for the paper, "Stability of Nonlinear Sampled-Data Control System," which appeared in the IRE TRANSACTIONS OF AUTOMATIC CONTROL.

Professors G. M. Kranc and P. E. Sarachik of Columbia University received an award for the second best paper presented at the 1962 Joint Automatic Control Conference. The title of their paper was "An Application of Functional Analysis to the Optimal Control Problem." This is the second year in a row that an AFOSR paper has won a major award at the Joint Automatic Control Conference.

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